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A Nested Demand Shares Model of Artificial Marine Habitat Choice by Sport Anglers

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Abstract *There is growing public interest in the development of artificial habitats to enhance and diversify coastal marine resources for recreational and commercial uses. In this article, a hierarchical discrete choice model of recreational demand for artificial habitat is presented using a nested multinomial logit analysis of artificial and natural habitat site choice by sport anglers. The model can be used to evaluate the effects of site characteristics and socioeconomic attributes of individual sport anglers on the share allocation of marine fishing trips and to estimate the economic benefits of new artificial habitat. An empirical application using survey data from sport anglers in southeast Florida is reported. The model parameters are used to estimate the expected use benefits and distributional implications of alternative new artificial habitat sites. Extensions and limitations of the model for artificial habitat planning are considered.*

Keywords recreational use benefits, discrete choice models, nested multinomial logit, artificial marine habitat.

Introduction

Artificial habitats are man-made structures (benthic reef structures, platforms, and floating devices) placed in coastal waters to enhance marine resources for both sport and commercial anglers and divers. Local civic groups and government organizations throughout the world have been deploying artificial habitats for decades (Stone 1985), but habitat development has only recently been recognized as a significant component of coastal resource management in the United States. The National Fishing Enhancement Act of 1984 (P.L. 98-623) established a planning process to develop artificial habitats and the subsequent National Artificial Reef Plan (U.S. Department of Commerce 1985) provided guidelines for site-specific planning sensitive to local resource use demands.

Despite the growing public interest in artificial habitat development, there has been little formal research on the effects of siting and design features on recreational user choice of artificial versus natural marine habitats and the application of economic models to measure the benefits of new habitat sites (Milon, forthcoming). This is an important part of efficient site planning since recreational users, and sport anglers in particular, are often the principal beneficiaries of artificial habitat development (Gordon and Ditton 1986).

Economic models of marine recreation behavior have addressed two components of sport fishing demand: (1) the trip generation process to determine the total number of fishing trips during a given time period (season, year), and (2) the trip distribution process to select specific sites for fishing. Trip generation studies have focused primarily on the demand for fishing within broad coastal regions such as the Chesapeake Bay (e.g., McConnell and Strand 1981). Trip distribution studies have examined the allocation of fishing trips across more narrowly defined coastal areas (e.g., coastal counties) as a function of area-specific cost and quality characteristics (e.g., Morey and Rowe 1985). Bockstael et al. (1986) have proposed an innovative approach to marine recreation demand estimation using a joint trip generation/distribution model of sport angler's demand for artificial marine habitat. Their model focused on the effect of natural and artificial habitat accessibility from coastal areas on the distribution of fishing trips during a time period (a discrete choice process) and the number of trips in the period (a continuous choice). The discrete choice model described two location decisions: the choice of coastal area to launch a boat and the choice of natural or artificial habitat from each launch area. The latter choice was described as a function of the average natural and artificial habitat characteristics in each area.

The analysis in this article complements and extends Bockstael et al.'s discrete choice model by considering: (1) the effect of site-specific characteristics of natural and artificial habitat sites on the allocation of marine fishing trips, (2) the degree of similarity between groups of sites such as near-shore and offshore sites, and (3) the importance of individual angler tastes and socioeconomic attributes for fishing site and habitat choice. These extensions provide information about marine sport anglers' preferences and site selection processes. In addition, changes in the allocation of fishing trips and the associated economic benefits due to new artificial habitat development can be estimated more accurately with a model that accounts for these dimensions of sport anglers' choice.

The discrete choice model specification and estimation are described for sport anglers' site choices in southeast Florida. This area, and Dade County (Miami) in particular, is an ideal setting for artificial marine habitat choice analysis. Since the early 1970s the county has had an organized, well-publicized artificial reef program that has developed seven major sites consisting of clustered derelict vessels. These sites are distributed along the continential shelf at depths of 15 fathoms or more in order to minimize hazards to maritime shipping traffic and natural reef habitat. Due to the site locations, sport anglers can be observed to make an explicit decision to travel offshore to use the sites and thereby pass up near-shore sites in Biscayne Bay or shallow water natural reefs along the coast. This setting suggests a natural sequence of discrete decisions by sport anglers on each trip as to the choice of near-shore or offshore fishing and the choice of artificial or natural habitat sites given the decision to go offshore.

A behavioral discrete choice model of habitat and site share allocation is presented here and details about specification of the probabilistic choice utility function are discussed. Specification tests for alternative forms of the choice function are considered. Procedures for deriving estimates of use benefits for new artificial habitat site development are also discussed. Empirical results using data from a survey of sport anglers in Dade County, Florida are presented. The empirical results are used to evaluate demand share elasticities for habitat and site characteristics and to estimate the distribution of use benefits from alternative new artificial habitat site locations. The final section provides a discussion on the use of demand share models in artificial habitat planning.

Nested Choice Model Structure

The southeast Florida coast is similar to many other coastal areas in that artificial habitat development is constrained by various navigational, geologic, hydrographic, and institutional factors. Typically this means that habitats are restricted to specific areas. To identify the factors that determine the allocation of fishing trips to artificial and natural habitats, the location of sites can be used to construct a decision hierarchy that represents the choices for an individual private boat sport angler deciding whether to use a specific habitat site.

For example, in the case of the Dade County reef system, these choices can be represented with the tree diagram in Figure 1. The angler's choice of offshore or near-shore ($i = 1, 2$) provides a transition to the next decision node of artificial reef or nonreef habitats ($j = 1, 2$), with the final node the choice of sites ($k = 1, \ldots, K$). Each transition node is defined by the group of alternatives below the node and each transition is a progression toward groups of similar alternatives. Choices on lower branches of the tree are conditioned on prior choices at each transition node. Thus the hierarchical structure implies that the artificial reef sites are more similar to each other than to the offshore nonreef sites, but both groups of offshore alternatives are more similar to each other than to the near-shore alternatives.

Model Development

This discrete choice problem can be modeled in general form by assuming that the number of fishing trips by each angler during a time period (season or year) is predetermined by exogenous factors, but each trip is a utility maximizing choice of which site to use.[1] Letting g represent the n^{th} angler's decision to visit site k on the f^{th} choice occasion ($g_{kf} = 1$ if the k^{th} site is chosen, 0 otherwise) and given the total trip constraint: $\Sigma_k \Sigma_f g_{kfn} = \hat{v}_n$, where $\hat{v}$ is the total number of fishing trips, the utility maximizing share allocation problem can be expressed as

$$\begin{aligned} &\text{Max } U(g_{kfn}(q_k), z_n) \qquad \forall f = 1, \ldots, \hat{v}_n, \\ &\text{s.t. } \sum_k p_{kn} g_{kn} + p_z z_n \leq y_n, \\ &\qquad \sum_k t_{kn} g_{kn} + t_{zn} z_n \leq \ell_n, \end{aligned} \tag{1}$$

where the term $g_k(q_k)$ reflects the influence of site characteristics, q, on site choice decisions, z is a Hicksian composite good, p_k and p_z are the monetary prices of site trips and the composite good, respectively, y is money income, t_k and t_z are the time prices of site trips and other goods, respectively, and ℓ is the total time budget. For any single trip, the angler selects the site with the highest utility from his or her choice set, C_n. This set includes the site alternatives from the universe of all existing sites that are both feasible and known to the angler. Anglers who do not know the location of artificial habitat sites, for example, would not have these alternatives in their choice set.

To the outside observer who can never observe individual utility with certainty, the probability that site k will be selected can be expressed in a discrete choice, random utility framework as:

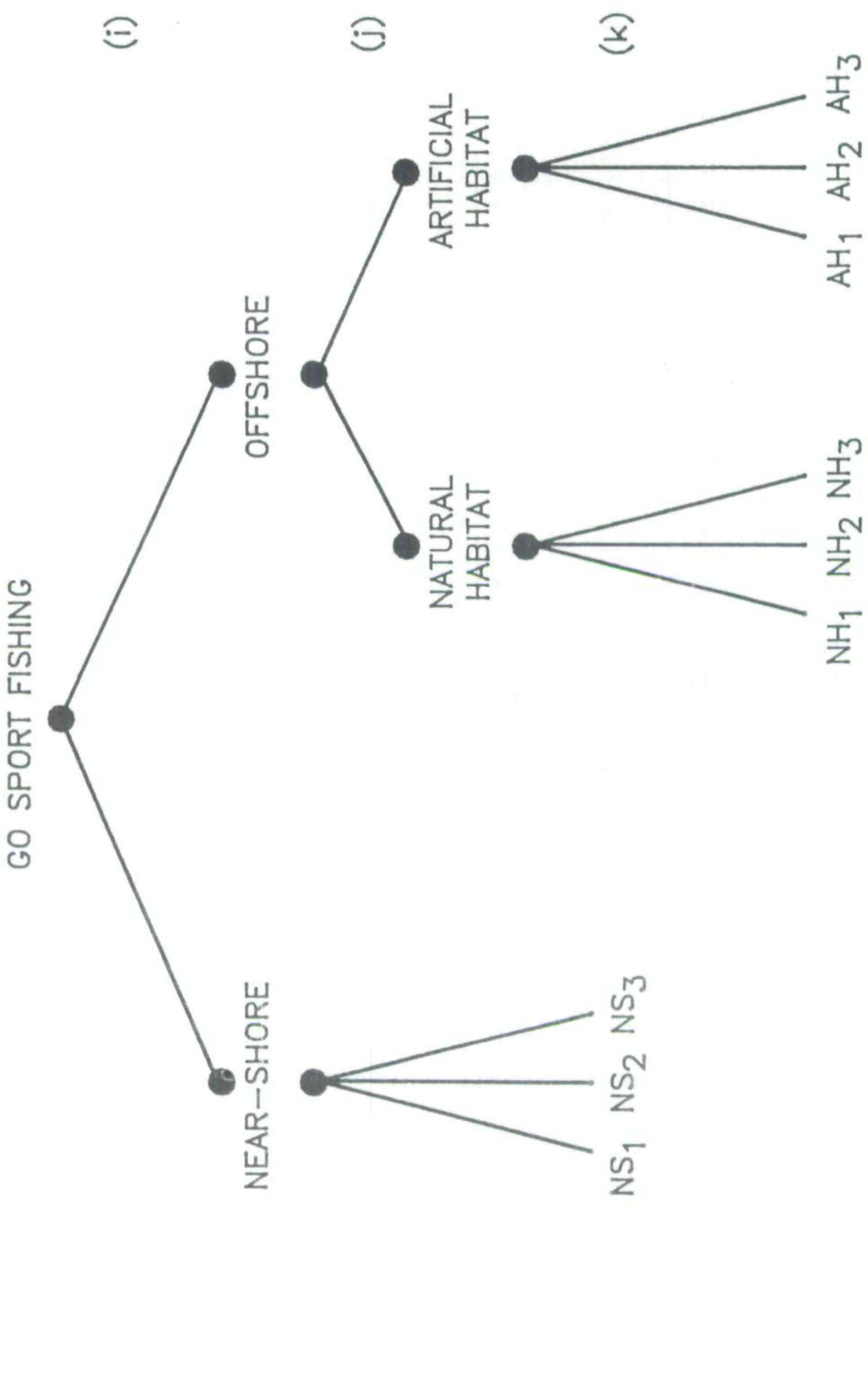

Figure 1. A choice hierarchy for artificial habitat use.

$$P_n(k) = P\left[\max_{k \in C_n} U_{kn} \geq \max_{k' \in C_n} U_{k'n}, \forall k \in C_n, k \neq k'\right], \tag{2}$$

where U represents an indirect utility function. Assuming U can be partitioned into systematic, V, and random, ϵ, components and that utility is a function of site characteristics, q_k, and user-specific attributes of the angler, s, the site choice problem can be written

$$P_n(k) = P[V(q_k, s_n) + \epsilon(q_k, s_n) \geq V(q_{k'}, s_n) + \epsilon(q_{k'}, s_n), \forall k \in C_n, k \neq k'] \tag{3}$$

Estimating the choice probabilities for (3) from the set of actual choices leads directly to predicted demand shares at the individual or aggregate level (Manski 1977). But the estimation model requires an explicit behavioral assumption about the structure of the decision process. One approach is to assume that site choices are independent and mutually exclusive so that the ratio of the probabilities of choosing one site over another is unaffected by the attributes of any other sites in the choice set. Following a well-known result due to Luce (1977), the probabilities in (3) can be estimated as a multinomial logit (MNL) model by assuming the random components are independently and identically distributed (iid) with the Gumbel distribution. Letting $V_k(\cdot) = V(q_k, s_n)$ for notational simplicity, the MNL share probabilities can be expressed

$$P_n(k) = \exp V_k(\cdot) / \sum_{k' \in C_n} \exp V_{k'}(\cdot). \tag{4}$$

The MNL structure is computationally convenient but an important drawback of the iid assumption is the absence of attribute or taste correlation between sites. In the context of the choice hierarchy in Figure 1, this implies that the choice between a near-shore and offshore site is not affected by the presence of other offshore sites. In addition, if a new choice such as an artificial habitat site is introduced, the site attracts trip shares *proportionally* from all other sites, regardless of substitutability. Although there has been little consideration of the plausibility of this proportionality assumption in angler site decisions, there is sufficient evidence from consumer product and transportation studies (e.g., Ben-Akiva and Lerman 1985; Currim 1982; Small 1987) to suggest the decision structure is too restrictive. Hausman and McFadden (1984) have developed a test of the independence specification for specific choice sets.

An alternative decision structure is a hierarchical or nested recursive process such as that represented in Figure 1. In this structure, an angler is assumed to make a decision at each transition node conditioned on prior choices and the expected value of alternatives below the node. This conceptualization of the decision as a "utility tree" can be represented as an additively separable utility function mapping the multidimensional alternatives into a single utility value (Strotz, 1957):

$$U_{ijk} = U_i + U_{j|i} + U_{k|ij} \tag{5}$$

where the subscripts represent the transition levels previously defined for Figure 1. The conditional structure of the problem suggests a vertical aggregation of information "up the decision tree" from site choice (k) to offshore/near-shore choice (i) based on the composite utility of choices below each node (Williams 1977). The implication of this conditional recursive structure is that the random utility maximization in (2) can be restated as

$$P_n(i) = P\left[\max_{i \in C_n} U_{in} + \hat{U}_{j \in in} + \hat{U}_{k \in i,jn} \geq \max_{i' \in C_n} U_{i'n} + \hat{U}_{j \in i'n} + \hat{U}_{k \in i,jn} \quad \forall i \in C_n,\ i \neq i'\right] \tag{6a}$$

$$P_n(j) = P\left[\max_{j \in C_{in}} U_{j|in} + \hat{U}_{k \in j|in} \geq \max_{j' \in C_{in}} U_{j'|in} + \hat{U}_{k \in j'|in},\ \forall j \in C_{in},\ j \neq j'\right] \tag{6b}$$

$$P_n(k) = P\left[\max_{k \in C_{ijn}} U_{k|i,jn} \geq \max_{k' \in C_{ijn}} U_{k'|ijn},\ \forall k \in C_{ijn},\ k \neq k'\right] \tag{6c}$$

where $\hat{U}$ is the composite utility of lower level choices. In this specification the conditioning is from near-shore/offshore to site choice. The composite utility or "accessibility index" can be determined by aggregating over the utilities associated with selected choices from each nest in the hierarchy:

$$\hat{U}_{k \in i,jn} \equiv A_{ij} = \ln\left(\sum_{k \in j'|in} \exp\left(V_k(\cdot)\right)\right), \tag{7}$$

and

$$\hat{U}_{j \in in} = AA_i = \ln\left(\sum_{j \in in} \exp(V_j(\cdot) + \alpha A_{ij}\right) \tag{8}$$

where V is again the deterministic component of indirect utility.

The direction of conditioning indicates correlations and differential rates of substitution among alternatives that can be evaluated to test the plausibility of the nested recursive structure relative to the independent structure of the MNL model. McFadden (1981) has demonstrated that the demand share probabilities for a nested random utility maximization such as (6a)–(6c) can be estimated as the nested multinomial logit (NMNL) equations[2]:

$$P_n(k|ij) = \exp V_k(\cdot) / \sum_{k' \in C_{ijn}} \exp V_k(\cdot) \tag{9a}$$

$$P_n(j|i) = \exp V_j(\cdot) + \alpha A_{ij}) / \sum_{j' \in C_{in}} \exp\left(V_{j'}(\cdot) + \alpha A_{ij}\right) \tag{9b}$$

$$P_n(i) = \exp\left(V_i(\cdot) + \gamma AA_i\right) / \sum_{i' \in C_n} \exp\left(V_{i'}(\cdot) + \gamma AA_i\right) \tag{9c}$$

where the parameters α, γ are the coefficients on the accessibility indices at each transition node. The equations are estimated in what may seem like a reverse order so that the utility information from lower level site alternatives can be reflected in higher level choices. The proper nesting of site alternatives depends on the correlations across alternatives due to unobserved site attribute and angler taste factors and can be evaluated with the estimated coefficients on the accessibility indices. Coefficient estimates in the unit interval (i.e., $0 \leq (\alpha, \gamma) \leq 1$) indicate greater substitutability within than among groups of site alternatives. In the present context, α is less than 1 if offshore anglers substitute artificial habitat sites more easily than they switch to natural habitat sites and γ is less than 1 if anglers substitute offshore sites more easily than they switch to near-shore sites. Coefficient estimates equal to 1 indicate that the nesting structure is invalid and the independent structure of the MNL model is more appropriate. Furthermore, coefficient estimates in the unit interval are a sufficient condition for the nested model to be consistent with utility maximization (McFadden 1981). This sequential estimation procedure uses maximum likelihood at each step and yields unbiased coefficient estimates, but the variance-covariance matrices beyond the first step must be corrected to obtain efficient standard errors (Amemiya 1978).

Differential rates of substitution across groups of sites also allow for more realistic assessment of changes in site share allocations than with the proportionality assumption in the MNL model. If the postulated nesting structure is valid, a new artificial habitat site will attract more anglers from other artificial habitat sites than from offshore natural habitat sites. In addition, the share reallocation to a new site for near-shore anglers will be less than would occur under proportionality. This more detailed specification of differences in anglers' site preferences in the nested demand shares framework suggests that user demand and benefit estimates will more accurately measure the socioeconomic impacts of artificial habitat development.

Empirical Specification

In the random utility framework, correlations across alternatives depend on random or unobserved site characteristics and user-specific attributes tastes that enter the utility function ($U_n = V(q, s) + \epsilon(q, s)$). The objective of empirical specification of the utility function is to correctly account for the ways observable site characteristics and user attributes influence choice and thereby reduce random error. From the theoretical share allocation model given by (1), it can be hypothesized that the deterministic component of utility from site choice is given by the general expression:

$$V_{kn} = V(p_{kn}, p_{zn}, t_{kn}, q_k, s_n, y_n) \tag{10}$$

To facilitate computation, the indirect utility function (10) can be restricted to a linear-in-parameters function, but economic theory provides little guidance for the exact form. One approach is to assume a specific utility function that satisfies certain desirable economic properties (e.g., Morey 1985). The disadvantage of this approach is a possible misspecification of the preference function and a loss of generality. An alternative approach is to consider a general specification for which different types of specification problems (i.e., alternative explanatory variables and decision structures) can be considered. One such general specification that is consistent with a utility tree is an additive specification:

$$V = \beta_1 x_1 + \beta_2 x_2 \tag{11}$$

where the x's are variables in the utility function (10) and the β's are coefficients to be estimated.

However, a general specification still requires specific assumptions about measures for the explanatory variables in (10). For example, specification of the monetary travel price variable, p_{kn}, is straightforward since the only relevant cost for open-access marine fishing sites is the variable expense of site use (e.g., fuel, bait). However, specification of the time price variable, t_{kn}, is more ambiguous. Since Cesario and Knetsch's (1970) argument that the exclusion of time costs biases welfare estimates from travel demand models, a number of alternative specifications have been applied in recreation studies.[3] The most common is to set the shadow price of time equal to the full, or some fractional, average wage rate and add it to the monetary travel costs (e.g., Bishop and Heberlein 1979; Morey and Rowe 1985). This approach requires an assumption that leisure and work can be substituted at a constant wage rate. Another specification is to leave travel time as a separate variable with no direct monetary cost (e.g., Gum and Martin 1975) or to impute the monetary cost from the marginal rate of substitution between travel cost and travel time (e.g., McConnell and Strand 1981). Another specification suggested by Bockstael et al. (1987) recognizes that the value of time is unique to an individual's employment situation. Individuals who have selected an employment alternative that permits marginal tradeoffs between work and leisure would value time at their marginal wage rate. These time costs can be directly added to monetary travel costs. For those individuals who lack this flexibility, time enters the specification as a separate variable, but the opportunity cost of travel time is not directly identifiable without further assumptions about leisure activity tradeoffs (Truong and Hensher 1985). Whereas these alternatives suggested by economic theory provide some guidance for specifying the time variable, none are conclusive *a priori* since the value of time will depend on the individual's alternatives for travel time and the importance of travel time in the specific recreation activity.

Economic theory also provides limited guidance for the proper partitioning of (11) to be consistent with the decision structure and taste variations suggested by the utility model (6a)–(6c). Horowitz (1980) has demonstrated that a major source of specification error in site choice models is the exclusion of relevant taste and socioeconomic attributes. One approach that can provide insights into this specification problem is to consider general household production theory.[4] Recreationists can be viewed as purchasing private inputs (both variable and fixed) and combining them with publicly provided inputs (e.g., wildlife stocks, facilities) and the recreationist's household technology to produce a flow of services from which the household derives utility (Bockstael and McConnell 1981). A major limitation of this approach is that it is not possible to separately identify taste and technology parameters without strong assumptions about the nature of the production technology or other restrictions on the choice problem. However, in the context of discrete site choice decisions, it may be useful to consider observable angler expenditures for fishing technology and information gathering as proxies for unobservable determinants of angler tastes. Combined with observable socioeconomic variables, these attributes of the decision maker provide a way to reduce the unobserved error in estimation.

For example, consistent with (6a) and (6b), the indirect utility function can be partitioned into site choice and habitat choice components as:

$$V_{k|jn} = V_k(p_{kn}, t_{kn}, q_{kn}), \tag{12a}$$

and

$$V_{j|in} = V_j(e_{jn}, s_{jn}, A_{ij}) \tag{12b}$$

where e_{jn} is a vector of production technology attributes of the angler that relate to habitat choice (e.g., electronic site detection equipment). The empirical specification (12a) indicates that travel cost, time, and site quality are generic variables for site choice. Each variable is restricted so that the marginal (dis)utility of the variable is the same across all sites for each individual. The accessibility index provides the composite utility of each site grouping for (12b), but total utility at this level is also a function of the alternative-specific variables e_{jn} and s_{jn}. These variables take a specific value for only one of the habitat alternatives and exert a shift effect on preferences, thereby helping to account for variation in tastes across habitat group alternatives.[5]

Similarly, the offshore/near-shore utility component (6c) can be specified:

$$V_{in} = V_i(e_{in}, s_{in}, AA_i) \tag{12c}$$

where e_{in} are production technology attributes related to offshore/near-shore choice (e.g., size and power of the angler's boat) and the s_{in} reflect taste variation due to socioeconomic factors (e.g., age of the angler). These variables again have a shift effect on preferences that changes the composite utility of prior choices measured with the accessibility index, AA_i. Prior research on marine anglers' travel behavior suggests that technology attributes are determinants of distance travelled from shore (Ditton et al. 1980).

Use Benefit Estimation

Changes in an angler's site choice set due to the addition or deletion of sites have welfare effects that can be measured from the estimated indirect utility function. Since coastal resource planners are concerned primarily about the benefits and costs of new site development, the most relevant example is the reallocation of demand shares due to the addition of a new site. A general indicator of angler welfare is given by the difference in each angler's maximum expected utility before and after the site addition (V^1_{in} and V^2_{in}, respectively), or

$$\sum_{i \in C_n} \int_{V^1_{in}}^{V^2_{in}} P(i|V_n)\, dV. \tag{13}$$

Utility is evaluated at the top level of the choice hierarchy because the benefits of a new site are determined by changes in the composite utility of lower level branches and these changes are conditional on higher level choice probabilities (equations (9a)–(9c)). A compensating variation (CV) measure of each angler's benefits can be defined as the maximum amount of money the angler would pay for a new site and be no worse off than the initial level of utility, or for the indirect utility function (10):

$$V_{in}[p^2_{kn}, q^2_{kn}, y_n - CV_n] = V_{in}[p^1_{kn}, q^1_{kn}, y_n], \tag{14}$$

where the other arguments in the utility function are suppressed without loss of generality.[6]

A numeric (ordinal) value of the indirect utility function can be derived from the formula (Williams 1977):

$$V_{in}[p_{kn}, q_{kn}, y_n] = \ln\left(\sum_{i \in C_n} V_{in}\right) + .577\ldots \tag{15}$$

Hanemann (1982) shows that for an additive, linear indirect utility function, (14) can be restated as:

$$\sum_{i \in C_n} \exp V_{in}^2 \exp \beta_n CV_n = \sum_{i \in C_n} \exp V_{in}^1 \tag{16}$$

where β_n is the estimated income coefficient. Using the approximation $\exp z \approx (1 + z)$, CV can be estimated as:

$$CV_n = \left(\sum_{i \in C_n} \exp V_{in}^1 - \sum_{i \in C_n} \exp V_{in}^2 \right) \Big/ \sum_{i \in C_n} \beta_n \exp V_{in}^2 \tag{17}$$

For the aggregation of composite utility through the nested choice probabilities (9a)–(9c), the use benefit estimation formula is given by:

$$CV_n = \left(\sum_{i \in C_n} \exp V_{in}^1(\cdot) + \gamma AA_{in}^1 \right) - \sum_{i \in C_n} \exp (V_{in}^2(\cdot) + \gamma AA_{in}^2)) \Big/ \sum_{i \in C_n} \beta_n \exp (V_{in}^2(\cdot) + \gamma AA_{in}^2). \tag{18}$$

This procedure for welfare analysis allows differences in angler's tastes and technology to be reflected in individual benefit measures of new site development. However, because the parameters of the nested demand shares model are estimated across individual fishing trip decisions, the estimated CV is only a per trip measure. Total individual benefits are determined by multiplying the per trip measure by the reported number of fishing trips per period (season, year) for each angler. Since benefits are measured at the individual level, the welfare analysis can be extended to consider the relative benefits of alternative new site locations and the distributional consequences for different socioeconomic groups.

Study Details and Empirical Results

Data Collection

To evaluate anglers' decision processes for choosing artificial marine habitat in Dade County, a sample was selected from boat registration files using a general stratified sampling rule with proportional allocation by zip code. A survey questionnaire was mailed in two separate waves of 1,800 units at six-month intervals during 1985. The overall response rate (excluding nondeliverables) was 45 percent of which approximately 75 percent, or 887 respondents, had participated in salt water fishing during the sample period (Milon 1987).

Respondents who had participated in some fishing activity during the prior six months reported the number of trips to each near-shore, offshore, and artificial reef site and the launch site typically used for trips to each fishing site.[7] Since all respondents were local residents, a trip was defined as a fishing day where the majority of a day's activity occurred at a certain site. Due to the extensive system of waterways in Dade County with many private docks, marinas, and other berthing facilities, there was little variation in each angler's launch site choice across different destinations. Therefore, it was assumed that the launch site decision was determined by factors exogenous to fishing site choice and not considered in this analysis.

Catch data on the most recent trip were also reported for each site. The study area has a large number of native and seasonal species in the fishery. Presurvey trials with the questionnaire indicated that most respondents had difficulty identifying specific species. Therefore, only total number and weight of fish kept or released were collected and used for aggregate measures of site fishing quality. Both the mean and the coefficient of variation of catch per unit effort (number of anglers times number of hours fished) were used as explanatory variables for site fishing quality. The mean catch rate is an indicator of average quality at a site, whereas the coefficient of variation is a simple indicator of the variability in site quality. Both measures attribute quality differences solely to catch weight and disregard quality effects due to species composition or number of the catch.

Since travel costs are a primary determinant of destination choice and there are no standardized measures of boat travel costs comparable to those for auto travel, respondents were asked to estimate average (normal seas) fuel use per hour of running time and running speed. Travel costs (TC) to each site based on nautical distance were calculated with the formula:

$$TC_{kn} = ((D_{kn}/RS_n) \times BFM_n \times \$2.50) \tag{19}$$

where D is the distance to the k^{th} destination from the n^{th} angler's launch site, RS is the angler's running speed (knots) per hour, BFM is the boat fuel mileage per hour, and \$2.50 is the average round-trip cost per gallon of fuel. Travel time (TT) to a site is D_{kn}/RS_n; since travel cost varies by the individual-specific parameter BFM, travel cost and travel time are not collinear.

Other socioeconomic, attitudinal, and experience data were also collected. The latter is important because a lack of information about the availability of certain destinations limits the number of options in an angler's choice set. This is particularly relevant in this application because the Dade County reefs are not marked by buoys. Anglers must rely on shore line-ups or electronic detection to find a specific site. In the questionnaire, anglers were asked whether they knew about the existence of the artificial reefs in order to determine each angler's choice set. A listing of model variable names, definitions and mean values for the sample is provided in Table 1.

Nested Model Estimation

The site choice level equation (12a) can be estimated as a function of travel cost, travel time, and site-specific quality characteristics such as catch rates and the age of artificial habitat sites. The age characteristic is relevant since fish populations at artificial habitat sites do not reach equilibrium instantaneously and information about these sites may disseminate slowly through the angler community.[8] To determine the proper specification of the travel cost and travel time variables, four different site choice models were estimated. The alternative specifications of travel cost and travel time are:

Model 1: $$V^* = \beta_{11}((TC_{kn} + (TT_{kn} \cdot W_n))/Y_n), \tag{20a}$$

Model 2: $$V^* = \beta_{12}((TC_{kn}/Y_n) + \beta_{32}((T_{kn} \cdot W_n))/Y_n), \tag{20b}$$

Model 3: $$V^* = \beta_{13}((TC_{kn} + (TT_{kn} \cdot W_n))/Y_n) + \beta_{33}(0) \tag{20c}$$

Table 1
Variable Names, Definitions, and Mean Values for the Sample

Variable	Definition	Mean[a]	
TC	Travel cost from launch site to destination based on distance, running speed, fuel mileage, and fuel cost (in 1985 \$).	NS ONH OAH	6.56 11.36 12.41
TT	Travel time from launch site to destination based on distance and running speed (in minutes).	NS ONH OAH	20.76 35.52 38.76
PUEM	Mean pounds of fish (kept or released) per unit fishing effort for each site.	NS ONH OAH	2.68 3.70 6.45
PUECV	Coefficient of variation for pounds of fish per unit effort	NS ONH OAH	1.43 1.83 1.97
AS	Number of years since artificial reef structure first developed.		4.71
EQI	Boat equipment index: Loran, depth-finder, fish-finder and two-way radio (0–4).		2.09
OP	Angler's opinion of artificial habitat productivity relative to natural habitat (scalar value from 0 to 1 with 1 indicating strong opinion that artificial habitat is more productive).		0.28
RAC	Angler's race: 1 if Hispanic, 0 otherwise.		0.19
YBD	Number of years angler boated in Dade County.		18.50
MFDC	Membership in sport fishing or diving club.		0.12
Y	Angler's annual household income (\$).		49,703.98
BL	Length of boat angler used for salt water fishing.		22.24
EHP	Engine horsepower of angler's boat.		200.58
AGE	Angler's age.		45.20

[a]Mean values of the generic site variables are reported for the 3 site groups: near-shore, NS; offshore natural habitat, ONH; and, offshore artificial habitat, OAH.

or,

$$= \beta_{13}(TC_{kn}/Y_n) + \beta_{33}(TT_{kn}), \tag{20d}$$

Model 4:
$$V^* = \beta_{14}(TC_{kn}/Y_n) + \beta_{34}(TT_{kn}) \tag{20e}$$

where W is the angler's hourly wage rate. Model 1 derives from a constant work/leisure tradeoff assumption. Model 2 implies that work and leisure are not perfectly substitutable, but time has an identifiable opportunity cost. Model 3 corresponds to different work/leisure tradeoffs for anglers in the sample: equation (20c) is estimated for anglers who can substitute work for leisure time and (20d) is estimated for anglers with no substitution alternative.[9] Model 4 indicates that travel time is a constraint on site choice, but the opportunity cost of time cannot be identified. All monetary costs are divided by household income (which has been normalized on the price of the composite good, $p_{zn} = 1$) to assure that the indirect utility functions are homogeneous of degree 0 in prices and income and consistent with other conventional restrictions (Hau 1985).

Empirical results for the site choice equation using Models 1–4 are reported in Table 2. The site-specific quality variables are positive and highly significant across all models. The coefficients for PUEM and PUECV indicate that anglers prefer sites with higher average yields and greater variation in yield. This latter result suggests that anglers may be "risk-seekers" in that they select sites with a chance for heavier fish. Unfortunately the data do not permit a detailed evaluation of this result for specific species or seasons. The alternative-specific constants are significant and negative across all models indicating a relative preference for near-shore sites, all else held equal. The travel cost variable is significant in all models except Model 2 and travel time is highly significant in Models 2–4 where it enters as an independent variable. Since each model is based on a different assumption about work/leisure tradeoffs, the models are nonnested so that selection of the best specification is not clear-cut. Horowitz (1983) suggests that the correct specification from nonnested discrete choice models can be selected with the adjusted log-likelihood ratio index:

$$\hat{\rho}^2 = 1 - \frac{L(\beta) - \mathrm{K}/2}{L(0)} \tag{21}$$

where $L(\beta)$ and $L(0)$ are the final and initial log-likelihood values for the model, respectively, and K is the number of estimated parameters. The model with the highest $\bar{\rho}^2$ is the preferred specification. Computed values of $\bar{\rho}^2$ at the bottom of Table 2 indicate that Model 4 is the correct specification for this sample and choice set.

Further analysis of Model 4 provides information about the decision structure for site choice. The alternative-specific constants for offshore natural and artificial habitat capture the unobserved variables that influence site choice. If the estimated coefficients are equal, the offshore habitat choice has the same unexplained source of variation and a nested model structure for this choice would not be valid. A test of the equality hypothesis can be conducted with the statistic:

$$\tau = \alpha_{\mathrm{NH}} - \alpha_{\mathrm{AH}}/\mathrm{var}(\alpha_{\mathrm{NH}} - \alpha_{\mathrm{AH}})^{1/2} \tag{22}$$

where the α's are the estimated coefficients and the denominator is given by: $\mathrm{var}(\alpha_{\mathrm{NH}}) + \mathrm{var}(\alpha_{\mathrm{AH}}) - 2\,\mathrm{cov}(\alpha_{\mathrm{NH}}, \alpha_{\mathrm{AH}})$. The statistic has the t distribution. For Model 4, $\mathrm{cov}(\alpha_{\mathrm{NH}}, \alpha_{\mathrm{AH}}) = .0402$ and the computed ρ is 2.20, thereby rejecting the null hypothesis at the .05 level.

A more powerful test of the decision structure is Hausman and McFadden's (1984) specification test statistic for MNL models:

$$\mathrm{T} = (\beta_{\hat{\mathrm{C}}} - \beta_{\mathrm{C}})'(\mathrm{M}_{\hat{\mathrm{C}}} - \mathrm{M}_{\mathrm{C}})^{-1}(\beta_{\hat{\mathrm{C}}} - \beta_{\mathrm{C}}) \tag{23}$$

where $\beta_{\hat{\mathrm{C}}}$ and β_{C} are restricted and unrestricted coefficient vectors, respectively, and M denotes the appropriate covariance matrix. The statistic has the χ^2 distribution with the degrees of freedom given by the number of coefficients in the restricted model. Rejection of the null hypothesis that the coefficients of the restricted and unrestricted models are equal indicates that the unobserved factors influencing site choice are not independent. This implies that a MNL model is not appropriate and a nested model (or other model that permits correlation between choices) should be estimated.

The specification test was conducted for two restricted models. In the first, only near-shore sites were removed from the choice set and, in the second, only artificial habitat sites were deleted. The degrees of freedom were adjusted for the remaining parameters in the restricted model. Results of the test reported in Table 3 indicates rejection of the null hypothesis for both restricted models at the .05 level.

The coefficients for the second level of the model describe the choice of habitat conditioned on the decision to go offshore and are reported in the upper part of Table 4. The coefficient for the accessibility index (calculated from the coefficients for Model 4) at this stage is within the unit interval and significantly different from 0 at the 1 percent level. This result indicates that anglers more readily substitute sites within offshore habitat groups rather than across habitat groups. It is consistent with the decision hierarchy in the NMNL model and provides further evidence to reject a MNL specification of the choice function. The proximity of the accessibility coefficient to 0 suggests a relatively high degree of substitutability within habitat groups.

The negative value of the alternative-specific constant indicates a relative preference

Table 2

Estimated Coefficients for Alternative Specifications of Site Choice Given Offshore/Near-Shore and Habitat Choices

Variable Name	Model 1[a]	Model 2[a]	Model 3[a]	Model 4[a]
Offshore natural habitat constant	−1.221** (.447)[b]	−.633** (.298)	−.889** (.398)	−.567** (.201)
Offshore artificial habitat constant	−1.043** (.454)	−.498** (.237)	−683** (.271)	−.413** (.212)
Travel cost	−.039*** (.003)	−7.556 (21.859)	−69.514*** (20.552)	−402.053*** (35.412)
Travel time	—	−747.913*** (37.031))	−1.367*** (.073)	−.454*** (0.91)
Catch weight (PUEM)	−.394*** (.014)	.422*** (.013)	.415*** (.014)	.514*** (.056)
Catch variability (PUECV)	.559*** (.041)	.630*** (.033)	.618*** (.033)	.799*** (.113)
Age of site—specific to artificial habitat (AS)	.096*** (.007)	.106*** (.006)	.105*** (.007)	.079*** (.011)
Summary statistics at convergence				
Adjusted log-likelihood ratio ($\bar{\rho}^2$)	.094	.105	.103	.110
χ^2	1624.43***	1972.31***	1930.91***	2284.59***

[a]For all models the number of cases is 8,179 and the number of choices is 69,863.
[b]Figures in parentheses are the corrected standard errors.
*, **, *** indicate significance at the .1, .05, and .01 levels, respectively.

Table 3
Independence Specification Test Using Hausman-McFadden Statistic

Model	No. of Observations	Initial Log-Likelihood	Ending Log-Likelihood	Degrees of Freedom	T
Unrestricted	8,179	−17,061.67	−15,184.05	7	—
Restricted: Near-shore deleted	4,794	−9,131.22	−7,943.91	6	15.13**
Restricted: Artificial reefs deleted	5,789	−10,417.29	−9,760.13	5	14.55**

**Indicates significance at the .05 level.

for natural habitat, all other factors being equal. Other significant variables reflect the importance of alternative-specific user variables in the choice process. The equipment index (EQI) and opinion (OP) variables indicate that, as the types of locational equipment increase and the angler's perception that artificial habitats are more productive increase, the probability of selecting artificial habitat increases. This latter result indicates that anglers' perceptions and habitat choice decisions are generally consistent. Also, anglers of Hispanic origin and fishing club members are more likely to select artificial habitats. On the other hand, the years of boating experience is negatively related to artificial habitat choice. The significance of these socioeconomic influences indicates that the unexplained error in the choice model is reduced by accounting for observable angler-specific taste and socioeconomic variables.

The top level of the decision hierarchy (equation 12c) is described by the offshore/near-shore choice coefficients in the lower part of Table 4. The accessibility coefficient for this level is significantly different from 0 and indicates consistency with the behavioral hypotheses expressed in the nested choice structure. The negative coefficient for the off-shore constant indicates a relative preference for near-shore sites. Alternative-specific user technology variables are also important in that larger horsepower boats equipped with more electronic equipment are more likely to go offshore. Boat length is insignificant due perhaps in part to the length filter used for the sample frame. These relationships between angler boating equipment variables and offshore/near-shore choice are consistent with prior research on marine anglers' travel behavior (Ditton et al. 1980). Finally, the socio-economic variables age and income are significant at this level but negatively related to the offshore choice.

The explanatory power of the NMNL model as measured by the adjusted likelihood ratio index increases at each level and indicates that the model captures part of the complex interactions that determine anglers' destination choice. The pattern of increasing explanatory power indicates relatively greater unobserved sources of variability at the site choice level, which may be difficult to reduce without more detailed information about target specie objectives, trip duration constraints, seasonal effects, and weather conditions. In general, however, the predictive power of the model is comparable to other discrete choice models in the transportation literature (Ben-Akiva and Lerman 1985).

Elasticity Estimates

The estimated model can be used to measure the responsiveness of anglers' site choice allocations given exogenous changes in decision variables. In the NMNL demand shares model these aggregate "share elasticities" reflect changes in individual level choice probabilities for the existing set of choices defined in the model. Table 5 presents estimated share elasticities for three site characteristic variables across the three sets of habitat use groups. These elasticities were estimated by independently increasing each characteristic variable within a site group by 10 percent (holding all other variables constant at their mean) and calculating the new joint probability. The reader should note that these elasticities only measure changes in the shares of trips and not changes in the total number of trips. Hence, these elasticities are not directly comparable to elasticities derived from other specifications of the travel demand equations (e.g., Samples and Bishop 1985).

The elasticities indicate that anglers are more responsive to changes in travel cost than travel time, but they are most responsive to changes in site fishing quality as

Table 4

Estimated Coefficients for the Habitat Choice and Offshore/Near-Shore Choice Levels of the Nested Choice Model

Variable Name	Coefficient Estimate	Corrected Standard Error
Habitat Choice Given Offshore Choice		
Artificial habitat constant	−1.653***	.26
Accessibility index (A)	.196***	.03
Equipment index (EQI)	.445***	.04
Productivity opinion (OP)	1.659***	.17
Race (RAC)	.484***	.12
Years boating in Dade (YBD)	−.009**	.004
Club member (MFDC)	.176*	.10
Offshore/Near-Shore Choice		
Offshore constant	−2.429***	.20
Accessibility index (AA)	.139***	.02
Engine size (EHP)	.005***	.001
Boat length (BL)	.008	.009
Equipment index (EQI)	.289***	.04
Angler's age (AGE)	−.009**	.003
Income (Y)	−.010***	.01
Summary statistics at convergence	**Habitat Choice**	**Offshore/Near-Shore Choice**
Number of cases	4,838	8,179
Number of choices	9,676	16,358
Adjusted log-likelihood ratio	.17	.26
χ^2	1,024.67***	2,484.15***

*, **, ***Indicates significance at the .1, .05, and .01 levels, respectively.

Table 5
Estimated Share Elasticities by Habitat Use Group

Habitat Use Group	Travel Cost (TC)	Travel Time (TT)	Mean Pounds Per Unit Effort (PUEM)
Near-shore	−.286	−.153	1.497
Offshore/natural habitat	−.389	−.270	2.091
Offshore/artificial habitat	−.417	−.272	2.972

measured by the mean pounds per unit effort catch rate. Elasticities for the offshore habitat user groups are higher reflecting the substitutability within habitat groups identified earlier with the accessibility index coefficient. It is interesting to note that the offshore habitat groups' elasticities are similar except for the fishing quality variable. The higher elasticity for the artificial reef user group suggests that these anglers are quite responsive to catch rates and are more likely to change sites based only on differences in catch rates.

New Site Benefits

Estimating the economic use benefits from development of new recreation sites such as artificial habitats is an old but controversial issue in the recreation economics literature. The NMNL demand shares model is quite useful for such benefit estimation because: (1) location and characteristic details for the new site can be specified directly in the model, (2) the effect of a new site on both existing artificial habitat users and potential users can be identified, (3) benefit measures are derived for individual utility preferences and socioeconomic characteristics, and (4) properly designed sample results can be readily extrapolated to the population.

Benefits from the development of a new artificial reef site in the Dade County system can be estimated with the coefficients of the nested choice model and formula (18). First, three hypothetical new site locations (northern end of the county, central, and southern end) were designed based on a uniform set of site quality characteristics representative of existing artificial reef sites.[10] Then, travel costs and travel time to the alternative locations were computed using equation (19) for each angler based on the distance from the angler's launch site to each new location. The third step was to recompute the site level accessibility index (A_{ij}) for each angler and each new location using the estimated coefficients from the site choice level equation (Model 4 from Table 2) and the computed travel costs and travel time. These computed accessibility indices yield an ordinal measure of an angler's utility, but individual welfare is conditional on higher level choices. Thus the fourth step was to compute an "unconditional" utility measure at the top of the choice hierarchy by adding the recomputed site level indices to the subsequent habitat and near-shore/offshore choice equation (Table 4). Since these components of the utility function reflect angler's tastes and socioeconomic attributes, the unconditional utility measures are personalized to each angler in the sample. The computed utility measures are estimates of the expected utility after new site development; they were then combined with the initial utility measure to estimate each angler's benefits from a new site using formula (18).[11] The final step was to use the estimated per trip new site benefits to compute total benefits based on each angler's reported number of fishing trips.

This approach to economic benefit measurement produces individual benefit estimates so that the distribution of benefits in the sample can be described by standard location and variability statistics. In addition, the benefit measures can be aggregated by any socioeconomic attribute. For this analysis, individual angler benefits for the alternative sites were aggregated by income group to illustrate the distributional effects of siting decisions. Sample mean and total annual expected compensating variation (CV) for these new sites and income groups are reported in Table 6.

The results show that in terms of the mean CV by income group, the highest income group benefits the most and group 2 the least regardless of site location. Income group 2, however, dominates the total sample CV across all sites. Interestingly, the ranking of the three sites is the same across all income groups so different weights attached to each group's benefits would not alter the overall site benefit ranking. All mean CVs for the total sample are significantly different from 0 at the .01 level, but a multiple means test of the total sample mean CV by site could not reject the hypothesis that the means are equal at the .01 level. Thus for this sample of anglers and site selections, the expected benefits of a new site within these north-south boundaries are approximately the same.

It should be noted that these expected benefits are ex ante measures that result from an "instantaneous" reallocation of fishing trips across sites with the introduction of a new site. When used as a predictive-shares model, the NMNL equations describe a naive model of dynamic choice processes and the diffusion of information about new site characteristics. This limitation pertains to all multisite choice models and should be considered in policy analysis of siting decisions.

Given that the sample is representative of the Dade County private boat sport angler population (Milon 1987), extrapolating the mean individual benefit estimate for a new "central" reef site yields total annual benefits of $31,329 for the population of 17,405 anglers. Lower and upper bounds on total benefits can be computed from the 5th and 95th percentile of the individual benefit distribution; these bounds are $0.00 to $102,864, respectively. Assuming the site would be available in perpetuity with no change in (1) anglers' preferences for site characteristics, (2) anglers' socioeconomic and equipment attributes, (3) total fishing trips by the existing angler population, and (4) the total number of anglers, the mean present value of a new site at 3 and 7 percent capitalization rates is $1,044,300 and $447,557, respectively. These benefits should, of course, be considered with other economic benefits and site development costs in any evaluation of new site viability.

Discussion

Artificial fishery habitats offer marine resource managers an opportunity to design new fishing sites that are consistent with user group preferences. The nested demand shares model is a useful heuristic for understanding recreational anglers' preferences for marine habitat characteristics and it provides a practical framework for formal recreation demand analysis of artificial habitat development projects. This extension of Bockstael et al.'s (1986) discrete choice model for marine habitat choice illustrates the interdependence in habitat and site choice decisions between site characteristics and heterogeneous angler preferences and the hierarchical structure of these decisions. The model could be

Table 6
Expected Annual Compensating Variation for New Artificial Habitat by Location and Income Group

Site Location	Income Group[a]	Mean CV[b]	Sample Total CV
North	1	$2.03 (.07, 8.36)	$ 91.32
	2	1.64 (.00, 15.29)	940.24
	3	1.82 (.18, 12.07)	132.54
	4	3.11 (.18, 24.77)	102.63
	Total	1.75	$1,266.74
Central	1	$2.08 (.09, 9.01)	$ 93.67
	2	1.69 (.00, 16.08)	971.56
	3	1.88 (.19, 12.69)	137.18
	4	3.13 (.19, 23.90)	103.44
	Total	1.80	$1,305.85
South	1	$1.62 (.00, 6.85)	$ 72.86
	2	1.51 (.00, 13.48)	868.61
	3	1.73 (.19, 12.69)	126.38
	4	2.75 (.20, 17.87)	90.66
	Total	1.60	$1,158.52

[a]Income groups are: 1—under $25,000, 2—$25,001 to $49,999, 3—$50,000 to $74,999, and 4—over $75,000.
[b]Minimum and maximum values of the individual benefits within each income group are reported in parentheses.

readily adapted to identify the preferences of other recreational user groups such as sport divers and to estimate their use benefits from habitat development.

Nonetheless the nested shares model has some shortcomings. User preferences for target species and/or seasonal variability in stocks at fishing sites are not considered. Integrating these choice dimensions in a nested choice model may require additional transition branches that would markedly increase the computational burden, particularly in areas with numerous species. A more practical problem is the data requirements for the nested choice model. Detailed information on multiple site choices during seasonal or annual periods with corresponding individual angler socioeconomic profiles is not collected as part of standard federal and state marine recreational fishing surveys. This limitation could be overcome, however, with carefully designed (albeit costly) surveys for specific coastal areas.

In addition, the nested shares model is developed on the assumption that the total number of trips by an angler is constant. Changes in an angler's choice set such as the addition of a new artificial habitat site only reallocate trips between sites. This is a strong assumption, but the restriction may not be unrealistic for many coastal areas with well-established sport fisheries where the addition of an artificial habitat site is a relatively small change in the set of site alternatives. In other areas with declining or nascent sport fisheries, this restriction may be problematic especially for long-run analysis. One possible solution would be to estimate a properly specified discrete/continuous model of sport fishing demand in the area.

Finally, it should be noted that nonuse benefits from artificial habitat development cannot be measured with the model. Sport anglers and other recreational groups may perceive spillover benefits from habitat development through stock and/or diversity enhancement, reduced activity pressure at natural habitat sites, or simply through concern about coastal marine resource availability for future generations. The application of nonmarket valuation techniques to measure these diverse components of artificial habitat development benefits presents an exciting challenge for marine resource economists.

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Notes

1. The assumption in this analysis that the total trips are fixed departs from the joint trip generation/distribution model developed by Bockstael et al. (1986). Their model which allows total trips to vary with changes in launch area and habitat characteristics, but their empirical analysis suggests the linkage is not easy to identify. The total trip constraint employed here is commonly used in discrete choice travel demand models (e.g., Ben-Akiva and Lerman 1985) and suggests that institutional factors prescribe the total number of trip occasions. Theoretical considerations for specifying unconstrained joint models are discussed in Hanemann (1984).

2. The NMNL model assumes the errors have the independent extreme value distribution and is a special case of a more flexible specification using the generalized extreme value (GEV) distribution (McFadden 1978). Maddala (1983) provides a concise discussion of the relationship between the two specifications. Although the GEV model is less restrictive, Small (1987) indicates that the additional computational difficulty of a GEV model may not improve the statistical performance of a NMNL specification.

3. This discussion does not consider specification issues related to on-site time.

4. The purpose of this discussion is to explore the theoretical basis for including observable angler attributes in the utility function specification. The development of a complete model linking household production theory with discrete choice models is beyond the scope of this paper.

5. Another specification for (12a) and (12b) with different behavioral implications is an interactive alternative-specific model of the form:

$$V_{k|jn} = V_k(p_{kn}, t_{kn}, q_{kn} \cdot e_{jn}, q_{kn} \cdot s_{jn})$$

where e_{jn} and s_{jn} are again defined for one of the habitat alternatives. This specification implies that user-specific attributes (tastes) change the marginal (dis)utility of site characteristics but exert no other influence on preference. Morey (1981, 1985) uses this type of specification for skiing site choice by creating interactive effects between site terrain and a skier's ability level (described as "effective physical characteristics"). This approach quickly becomes very cumbersome with a large number of interactive effects. In addition, this specification implies that site choice is not hierarchical so that correlations between groups of sites cannot be tested.

6. Depending on the specification of the time constraint in the utility function, the welfare effects of time savings could also be considered.

7. To minimize problems of site delineation and identification, respondents were provided a detailed map of Dade County coastal waters, which identified specific landmarks and inlets, near-shore and offshore zones, major natural reefs, and artificial reef sites with a listing of the vessel names and water depth at each site. For this application, specific near-shore and offshore sites within each zone were created to differentiate particular fishing areas. These mini-zones were based on specific fishing spots that were commonly cited in local fishing guide books and in conversations with local anglers and the marine extension agent. Since the artificial reefs are composed of several individual vessels, each reef site also encompasses an area of variable dimensions (approximately .75 to 2.0 square nautical miles). This classification produced four near-shore, two offshore natural habitat, and seven offshore artificial habitat sites. For launch site information, respondents were asked to write in the address (in the case of private docks) or the name/location of marinas/boat ramps used for launching to each site visited. The numerous launch sites in Dade County were aggregated to seven primary launch areas to simplify travel cost calculations (Milon 1987).

8. There is conflicting scientific information about the dynamics of artificial marine habitat communities. Some reports indicate that structures have been colonized by fishes within a few hours after deployment. Bohnsack and Sutherland (1985) conclude that community equilibrium is usually achieved within one to five years, but seasonal fluctuations in species composition and numbers may have more influence on community structure than succession due to the age of the structure. There has been little biological research on structures as large as the Dade County artificial reefs.

9. To implement Models 1 and 2, average hourly wage data are required. Typically, wage rates are derived by dividing annual income by an arbitrary number of annual work hours (2,080 or 2,000). However, for Model 3, information on each angler's employment alternatives and *marginal* wage rates are required. Bockstael et al. (1987) suggest that this information can be obtained in a two-step process by first asking whether an individual could have worked on a single (average) choice occasion and then, if he/she could have worked, asking what the marginal wage would have been. In an interview pretest with local fishing club members, respondents were confused by this process because, although they could have worked, they had salary contracts with no specific hourly wage and many participated in profit-sharing plans. Also, no one had a second job that might pay an hourly wage. To overcome these problems and still attempt to discern each angler's work/leisure tradeoff, the process was revised to determine whether the respondent took time off from work to engage in marine recreation or whether he/she went on nonwork days: weekends, holidays, or vacation. All respondents were asked to report annual salary, the number of paid vacation days, and the number of hours worked in a typical week. Based on these responses, an hourly "wage" was computed by dividing annual salary by the annual hours worked plus paid vacation days. Respondents who indicated they took time off were categorized as having flexible work hours and those who fished only on nonwork days had fixed work schedules. This alternative process worked well in a second pretest and yielded a 90-percent completion rate in the mail survey for those who had fished during the survey period. Respondents who did not answer the questions are not included in the data set. The completion rate for these questions was significantly lower for other recreation groups who participated in the survey (e.g., divers).

10. Specifically, the site was defined as an area of 1 square nautical mile where derelict vessels had been in place for two years. The mean pounds per unit effort catch rate was 5.76 and a coefficient of variation of 2.70. Travel cost and time vary for each site and individual.

11. Formula (18) is based on Hanemann's (1982) derivation of the formula in equation (17)

from an indirect utility function of the form: $V_{in} = \beta_1 p_{kn} + \beta_2 q_{kn} + \beta_3 y_n$. The transformation normalizing travel cost by income in the utility specification used in this analysis causes a monotonic rescaling of the origin of the indirect utility function, but any monotonic transformation can represent the underlying preference ordering. Since welfare measures in the random utility framework are derived from differences in ordinal utility levels, relative differences in utility are not changed by a monotonic transformation.

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